Where:

K = 0.001 kWh/Wh conversion factor for watt-hours to kilowatt-hours; and

283 = representative average number of clothes dryer cycles in a year.

4.6 *Per-cycle combined total energy consumption expressed in kilowatt-hours.* Calculate the per-cycle combined total energy consumption, E_{CC}, expressed in kilowatt-hours per cycle and defined for an electric clothes dryer as:

$E_{CC} = E_{ce} + E_{TSO}$

Where:

E_{ce} = the energy recorded in 4.1, and

E_{TSO} = the energy recorded in 4.7, and defined for a gas clothes dryer as:

$E_{CC} = E_{cg} + E_{TSO}$

Where:

E_{cg} = the energy recorded in 4.4, and

E_{TSO} = the energy recorded in 4.7.

4.7 *Energy Factor in pounds per kilowatt-hour.* Calculate the energy factor, EF, expressed in pounds per kilowatt-hour and defined for an electric clothes dryer as:

$EF = W_{bonedry}/E_{ce}$

Where:

$W_{bonedry}$ = the bone dry test load weight recorded in 3.4.1, and

E_{ce} = the energy recorded in 4.1, and

and defined for a gas clothes dryer as:

$EF = W_{bonedry}/E_{cg}$

Where:

$W_{bonedry}$ = the bone dry test load weight recorded in 3.4.1, and

E_{cg} = the energy recorded in 4.4,

4.8 *Combined Energy Factor in pounds per kilowatt-hour.* Calculate the combined energy factor, CEF, expressed in pounds per kilowatt-hour and defined as:

$CEF = W_{bonedry}/E_{CC}$

Where:

$W_{bonedry}$ = the bone dry test load weight 3.4.1, and

E_{CC} = the energy recorded in 4.6

[76 FR 1032, Jan. 6, 2011]

APPENDIX E TO SUBPART B OF PART 430—UNIFORM TEST METHOD FOR MEASURING THE ENERGY CONSUMPTION OF WATER HEATERS

1. Definitions

1.1 *Cut-in* means the time when or water temperature at which a water heater control or thermostat acts to increase the energy or fuel input to the heating elements, compressor, or burner.

1.2 *Cut-out* means the time when or water temperature at which a water heater control or thermostat acts to reduce to a minimum the energy or fuel input to the heating elements, compressor, or burner.

1.3 *Design Power Rating* means the nominal power rating that a water heater manufacturer assigns to a particular design of water heater, expressed in kilowatts or Btu (kJ) per hour as appropriate.

1.4 *Energy Factor* means a measure of water heater overall efficiency.

1.5 *First-Hour Rating* means an estimate of the maximum volume of ''hot'' water that a storage-type water heater can supply within an hour that begins with the water heater fully heated (i.e., with all thermostats satisfied). It is a function of both the storage volume and the recovery rate.

1.6 *Heat Trap* means a device which can be integrally connected or independently attached to the hot and/or cold water pipe connections of a water heater such that the device will develop a thermal or mechanical seal to minimize the recirculation of water due to thermal convection between the water heater tank and its connecting pipes.

1.7 *Instantaneous Water Heaters*

1.7.1 *Electric Instantaneous Water Heater* Reserved.

1.7.2 *Gas Instantaneous Water Heater* means a water heater that uses gas as the energy source, initiates heating based on sensing water flow, is designed to deliver water at a controlled temperature of less than 180 °F (82 °C), has an input greater than 50,000 Btu/h (53 MJ/h) but less than 200,000 Btu/h (210 MJ/h), and has a manufacturer's specified storage capacity of less than 2 gallons (7.6 liters). The unit may use a fixed or variable burner input.

1.8 *Maximum gpm (L/min) Rating* means the maximum gallons per minute (liters per minute) of hot water that can be supplied by an instantaneous water heater while maintaining a nominal temperature rise of 77 °F (42.8 °C) during steady state operation.

1.9 *Rated Storage Volume* means the water storage capacity of a water heater, in gallons (liters), as specified by the manufacturer.

1.10 *Recovery Efficiency* means the ratio of energy delivered to the water to the energy content of the fuel consumed by the water heater.

1.11 *Standby* means the time during which water is not being withdrawn from the water heater. There are two standby time intervals used within this test procedure: $\tau_{stby,1}$ represents the elapsed time between the time at which the maximum mean tank temperature is observed after the sixth draw and subsequent recovery and the end of the 24-hour test; $\tau_{stby,2}$ represents the total time during the 24-hour simulated use test when water is not being withdrawn from the water heater.

1.12 *Storage-type Water Heaters*

1.12.1 *Electric Storage-type Water Heater* means a water heater that uses electricity as the energy source, is designed to heat and

store water at a thermostatically controlled temperature of less than 180 °F (82 °C), has a nominal input of 12 kilowatts (40,956 Btu/h) or less, and has a rated storage capacity of not less than 20 gallons (76 liters) nor more than 120 gallons (450 liters).

1.12.2 *Gas Storage-type Water Heater* means a water heater that uses gas as the energy source, is designed to heat and store water at a thermostatically controlled temperature of less than 180 °F (82 °C), has a nominal input of 75,000 Btu (79 MJ) per hour or less, and has a rated storage capacity of not less than 20 gallons (76 liters) nor more than 100 gallons (380 liters).

1.12.3 *Heat Pump Water Heater* means a water heater that uses electricity as the energy source, is designed to heat and store water at a thermostatically controlled temperature of less than 180 °F (82 °C), has a maximum current rating of 24 amperes (including the compressor and all auxiliary equipment such as fans, pumps, controls, and, if on the same circuit, any resistive elements) for an input voltage of 250 volts or less, and, if the tank is supplied, has a manufacturer's rated storage capacity of 120 gallons (450 liters) or less. Resistive elements used to provide supplemental heating may use the same circuit as the compressor if (1) an interlocking mechanism prevents concurrent compressor operation and resistive heating or (2) concurrent operation does not result in the maximum current rating of 24 amperes being exceeded. Otherwise, the resistive elements and the heat pump components must use separate circuits. A heat pump water heater may be sold by the manufacturer with or without a storage tank.

a. Heat Pump Water Heater with Storage Tank means an air-to-water heat pump sold by the manufacturer with an insulated storage tank as a packaged unit. The tank and heat pump can be an integral unit or they can be separated.

b. Heat Pump Water Heater without Storage Tank (also called Add-on Heat Pump Water Heater) means an air-to-water heat pump designed for use with a storage-type water heater or a storage tank that is not specified or supplied by the manufacturer.

1.12.4 *Oil Storage-type Water Heater* means a water heater that uses oil as the energy source, is designed to heat and store water at a thermostatically controlled temperature of less than 180 °F (82 °C), has a nominal energy input of 105,000 Btu/h (110 MJ/h) or less, and has a manufacturer's rated storage capacity of 50 gallons (190 liters) or less.

1.12.5 *Storage-type Water Heater of More than 2 Gallons (7.6 Liters) and Less than 20 Gallons (76 Liters)*. Reserved.

1.13 *ASHRAE Standard 41.1–86* means the standard published in 1986 by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., and titled Standard Measurement Guide: Section on Temperature Measurements.

1.14 *ASTM–D–2156–80* means the test standard published in 1980 by the American Society for Testing and Measurements and titled ''Smoke Density in Flue Gases from Burning Distillate Fuels, Test Method for''.

1.15 *Symbol Usage* The following identity relationships are provided to help clarify the symbology used throughout this procedure:

C_p specific heat capacity of water

E_{annual} annual energy consumption of a water heater

E_f energy factor of a water heater

F_{hr} first-hour rating of a storage-type water heater

F_{max} maximum gpm (L/min) rating of an instantaneous water heater rated at a temperature rise of 77 °F (42.8 °C) across the heater

i a subscript to indicate an ith draw during a test

M_i mass of water removed during the ith draw (i=1 to 6) of the 24-hr simulated use test

M^*_i for storage-type water heaters, mass of water removed during the ith draw (i=1 to n) during the first-hour rating test

M_{10m} for instantaneous water heaters, mass of water removed continuously during a 10-minute interval in the maximum gpm (L/min) rating test

n for storage-type water heaters, total number of draws during the first-hour rating test

Q total fossil fuel and/or electric energy consumed during the entire 24-hr simulated use test

Q_d daily water heating energy consumption adjusted for net change in internal energy

Q_{da} adjusted daily water heating energy consumption with adjustment for variation of tank to ambient air temperature difference from nominal value

Q_{dm} overall adjusted daily water heating energy consumption including Q_{da} and Q_{HWD}

Q_{hr} hourly standby losses

Q_{HW} daily energy consumption to heat water over the measured average temperature rise across the water heater

Q_{HWD} adjustment to daily energy consumption, Q_{hw}, due to variation of the temperature rise across the water heater not equal to the nominal value of 77 °F (42.8 °C)

Q_r energy consumption of fossil fuel or heat pump water heaters between thermostat (or burner) cut-out prior to the first draw and cut-out following the first draw of the 24-hr simulated use test

$Q_{r,\ max}$ energy consumption of a modulating instantaneous water heater between cut-out (burner) prior to the first draw and cut-out following the first draw of the 24-hr simulated use test

$Q_{r,\ min}$ energy consumption of a modulating instantaneous water heater from immediately prior to the fourth draw to burner

cut-out following the fourth draw of the 24-hr simulated use test

Q_{stby} total energy consumed by the water heater during the standby time interval $\tau_{stby,\ 1}$

Q_{su} total fossil fueled and/or electric energy consumed from the beginning of the first draw to the thermostat (or burner) cut-out following the completion of the sixth draw during the 24-hr simulated use test

T_{min} for modulating instantaneous water heaters, steady state outlet water temperature at the minimum fuel input rate

$\bar{T}_0$ mean tank temperature at the beginning of the 24-hr simulated use test

$\bar{T}_{24}$ mean tank temperature at the end of the 24-hr simulated use test

$\bar{T}_{a,\ stby}$ average ambient air temperature during standby periods of the 24-hr use test

$\bar{T}_{del}$ for instantaneous water heaters, average outlet water temperature during a 10-minute continuous draw interval in the maximum gpm (L/min) rating test

$\bar{T}_{del,\ i}$ average outlet water temperature during the *i*th draw of the 24-hr simulated use test

$\bar{T}_{in}$ for instantaneous water heaters, average inlet water temperature during a 10-minute continuous draw interval in the maximum gpm (L/min) rating test

$\bar{T}_{in,\ i}$ average inlet water temperature during the *i*th draw of the 24-hr simulated use test

$\bar{T}_{max,\ 1}$ maximum measured mean tank temperature after cut-out following the first draw of the 24-hr simulated use test

$\bar{T}_{stby}$ average storage tank temperature during the standby period $\tau_{stby,\ 2}$ of the 24-hr use test

$\bar{T}_{su}$ maximum measured mean tank temperature after cut-out following the sixth draw of the 24-hr simulated use test

$\bar{T}_{t,\ stby}$ average storage tank temperature during the standby period $\tau_{stby,\ 1}$ of the 24-hr use test

$\bar{T}^*_{del,\ i}$ for storage-type water heaters, average outlet water temperature during the *i*th draw (i=1 to n) of the first-hour rating test

$T^*_{max,\ i}$ for storage-type water heaters, maximum outlet water temperature observed during the *i*th draw (i=1 to n) of the first-hour rating test

$T^*_{min,\ i}$ for storage-type water heaters, minimum outlet water temperature to terminate the *i*th draw during the first-hour rating test

UA standby loss coefficient of a storage-type water heater

V_i volume of water removed during the *i*th draw (i=1 to 6) of the 24-hr simulated use test

V^*_i volume of water removed during the *i*th draw (i=1 to n) during the first-hour rating test

V_{10m} for instantaneous water heaters, volume of water removed continuously during a 10-minute interval in the maximum gpm (L/min) rating test

V_{max} steady state water flow rate of an instantaneous water heater at the rated input to give a discharge temperature of 135 °F ±5 °F (57.2 °C ±2.8 °C)

V_{min} steady state water flow rate of a modulating instantaneous water heater at the minimum input to give a discharge temperature of T_{min} up to 135 °F ±5 °F (57.2 °C ±2.8 °C)

V_{st} measured storage volume of the storage tank

W_f weight of storage tank when completely filled with water

W_t tare weight of storage tank when completely empty of water

^n_r recovery efficiency

$_P$ density of water

$\tau_{stby,\ 1}$ elapsed time between the time the maximum mean tank temperature is observed after the sixth draw and the end of the 24-hr simulated use test

$\tau_{stby,\ 2}$ overall standby periods when no water is withdrawn during the 24-hr simulated use test

1.16 *Tabletop water heater* means a water heater in a rectangular box enclosure designed to slide into a kitchen countertop space with typical dimensions of 36 inches high, 25 inches deep and 24 inches wide.

2. Test Conditions

2.1 *Installation Requirements.* Tests shall be performed with the water heater and instrumentation installed in accordance with Section 4 of this appendix.

2.2 *Ambient Air Temperature.* The ambient air temperature shall be maintained between 65.0 °F and 70.0 °F (18.3 °C and 21.1 °C) on a continuous basis. For heat pump water heaters, the dry bulb temperature shall be maintained at 67.5 °F ±1 °F (19.7 °C ±0.6 °C) and, in addition, the relative humidity shall be maintained between 49% and 51%.

2.3 *Supply Water Temperature.* The temperature of the water being supplied to the water heater shall be maintained at 58 °F ±2 °F (14.4 °C ±1.1 °C) throughout the test.

2.4 *Storage Tank Temperature.* The average temperature of the water within the storage tank shall be set to 135 °F ±5 °F (57.2 °C ±2.8 °C).

2.5 *Supply Water Pressure.* During the test when water is not being withdrawn, the supply pressure shall be maintained between 40 psig (275 kPa) and the maximum allowable pressure specified by the water heater manufacturer.

2.6 *Electrical and/or Fossil Fuel Supply.*

2.6.1 *Electrical.* Maintain the electrical supply voltage to within ±1% of the center of the voltage range specified by the water heater and/or heat pump manufacturer.

2.6.2 *Natural Gas.* Maintain the supply pressure in accordance with the manufacturer's specifications. If the supply pressure is

not specified, maintain a supply pressure of 7–10 inches of water column (1.7–2.5 kPa). If the water heater is equipped with a gas appliance pressure regulator, the regulator outlet pressure shall be within ±10% of the manufacturer's specified manifold pressure. For all tests, use natural gas having a heating value of approximately 1,025 Btu per standard cubic foot (38,190 kJ per standard cubic meter).

2.6.3 *Propane Gas.* Maintain the supply pressure in accordance with the manufacturer's specifications. If the supply pressure is not specified, maintain a supply pressure of 11–13 inches of water column (2.7–3.2 kPa). If the water heater is equipped with a gas appliance pressure regulator, the regulator outlet pressure shall be within ±10% of the manufacturer's specified manifold pressure. For all tests, use propane gas with a heating value of approximately 2,500 Btu per standard cubic foot (93,147 kJ per standard cubic meter).

2.6.4 *Fuel Oil Supply.* Maintain an uninterrupted supply of fuel oil. Use fuel oil having a heating value of approximately 138,700 Btu per gallon (38,660 kJ per liter).

3. Instrumentation

3.1 *Pressure Measurements.* Pressure-measuring instruments shall have an error no greater than the following values:

Item measured	Instrument accuracy	Instrument precision
Gas pressure	±0.1 inch of water column (±0.025 kPa)	±0.05 inch of water column (±0.012 kPa).
Atmospheric pressure	±0.1 inch of mercury column (±0.34 kPa)	±0.05 inch of mercury column (±0.17 kPa).
Water pressure	±1.0 pounds per square inch (±6.9 kPa)	±0.50 pounds per square inch (±3.45 kPa).

3.2 *Temperature Measurement*

3.2.1 *Measurement.* Temperature measurements shall be made in accordance with the Standard Measurement Guide: Section on Temperature Measurements, ASHRAE Standard 41.1–86.

3.2.2 *Accuracy and Precision.* The accuracy and precision of the instruments, including their associated readout devices, shall be within the following limits:

Item measured	Instrument accuracy	Instrument precision
Air dry bulb temperature	±0.2 °F (±0.1 °C)	±0.1 °F (±0.06 °C)
Air wet bulb temperature	±0.2 °F (±0.1 °C)	±0.1 °F (±0.06 °C)
Inlet and outlet water temperatures	±0.2 °F (±0.1 °C)	±0.1 °F (±0.06 °C)
Storage tank temperatures	±0.5 °F (±0.3 °C)	±0.25 °F (±0.14 °C)

3.2.3 *Scale Division.* In no case shall the smallest scale division of the instrument or instrument system exceed 2 times the specified precision.

3.2.4 *Temperature Difference.* Temperature difference between the entering and leaving water may be measured with any of the following:

a. A thermopile
b. Calibrated resistance thermometers
c. Precision thermometers
d. Calibrated thermistors
e. Calibrated thermocouples
f. Quartz thermometers

3.2.5 *Thermopile Construction.* If a thermopile is used, it shall be made from calibrated thermocouple wire taken from a single spool. Extension wires to the recording device shall also be made from that same spool.

3.2.6 *Time Constant.* The time constant of the instruments used to measure the inlet and outlet water temperatures shall be no greater than 5 seconds.

3.3 *Liquid Flow Rate Measurement.* The accuracy of the liquid flow rate measurement, using the calibration if furnished, shall be equal to or less than ±1% of the measured value in mass units per unit time.

3.4 *Electric Energy.* The electrical energy used shall be measured with an instrument and associated readout device that is accurate within ±1% of the reading.

3.5 *Fossil Fuels.* The quantity of fuel used by the water heater shall be measured with an instrument and associated readout device that is accurate within ±1% of the reading.

3.6 *Mass Measurements.* For mass measurements greater than or equal to 10 pounds (4.5 kg), a scale that is accurate within ±1% of the reading shall be used to make the measurement. For mass measurements less than 10 pounds (4.5 kg), the scale shall provide a measurement that is accurate within ±0.1 pound (0.045 kg).

3.7 *Heating Value.* The higher heating value of the natural gas, propane, or fuel oil shall be measured with an instrument and associated readout device that is accurate within ±1% of the reading. The heating value of natural gas and propane must be corrected for local temperature and pressure conditions.

3.8 *Time.* The elapsed time measurements shall be measured with an instrument that is accurate within ±0.5 seconds per hour.

3.9 *Volume.* Volume measurements shall be measured with an accuracy of ±2% of the total volume.

4. Installation

4.1 *Water Heater Mounting.* A water heater designed to be freestanding shall be placed on a ¾ inch (2 cm) thick plywood platform supported by three 2 × 4 inch (5 cm × 10 cm) runners. If the water heater is not approved for installation on combustible flooring, suitable non-combustible material shall be placed between the water heater and the platform. Counter-top water heaters shall be placed against a simulated wall section. Wall-mounted water heaters shall be supported on a simulated wall in accordance with the manufacturer-published installation instructions. When a simulated wall is used, the recommended construction is 2 × 4 inch (5 cm × 10 cm) studs, faced with ¾ inch (2 cm) plywood. For heat pump water heaters that are supplied with a storage tank, the two components, if not delivered as a single package, shall be connected in accordance with the manufacturer-published installation instructions and the overall system shall be placed on the above-described plywood platform. If installation instructions are not provided by the heat pump manufacturer, uninsulated 8 foot (2.4 m) long connecting hoses having an inside diameter of ⅝ inch (1.6 cm) shall be used to connect the storage tank and the heat pump water heater. With the exception of using the storage tank described in 4.10, the same requirements shall apply for heat pump water heaters that are supplied without a storage tank from the manufacturer. The testing of the water heater shall occur in an area that is protected from drafts.

4.2 *Water Supply.* Connect the water heater to a water supply capable of delivering water at conditions as specified in Sections 2.3 and 2.5 of this appendix.

4.3 *Water Inlet and Outlet Configuration.* For freestanding water heaters that are taller than 36 inches (91.4 cm), inlet and outlet piping connections shall be configured in a manner consistent with Figures 1 and 2. Inlet and outlet piping connections for wall-mounted water heaters shall be consistent with Figure 3. For freestanding water heaters that are 36 inches or less in height and not supplied as part of a counter-top enclosure (commonly referred to as an under-the-counter model), inlet and outlet piping shall be installed in a manner consistent with Figures 4, 5, and 6. For water heaters that are supplied with a counter-top enclosure, inlet and outlet piping shall be made in a manner consistent with Figures 7A and 7B, respectively. The vertical piping noted in Figures 7A and 7B shall be located (whether inside the enclosure or along the outside in a recessed channel) in accordance with the manufacturer-published installation instructions.

All dimensions noted in Figures 1 through 7 shall be achieved. All piping between the water heater and the inlet and outlet temperature sensors, noted as T_{IN} and T_{OUT} in the figures, shall be Type ''L'' hard copper having the same diameter as the connections on the water heater. Unions may be used to facilitate installation and removal of the piping arrangements. A pressure gauge and diaphragm expansion tank shall be installed in the supply water piping at a location upstream of the inlet temperature sensor. An appropriately rated pressure and temperature relief valve shall be installed on all water heaters at the port specified by the manufacturer. Discharge piping for the relief valve shall be non-metallic. If heat traps, piping insulation, or pressure relief valve insulation are supplied with the water heater, they shall be installed for testing. Except when using a simulated wall, clearance shall be provided such that none of the piping contacts other surfaces in the test room.

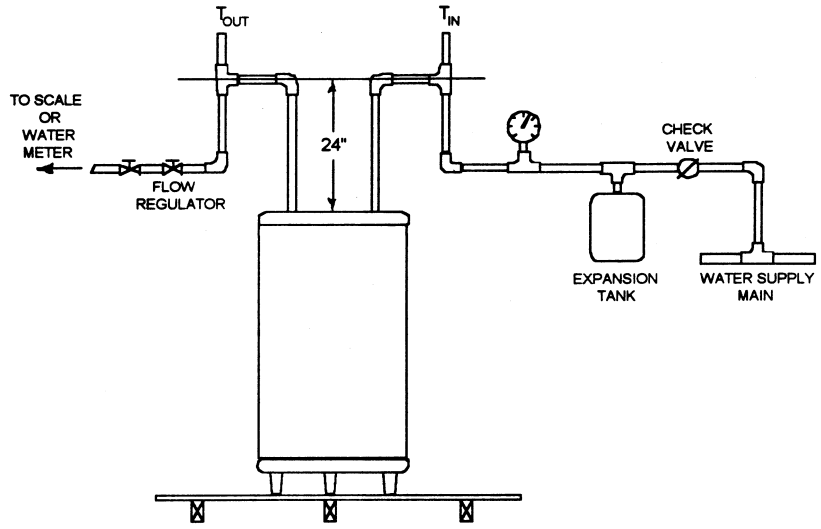

Figure 1.

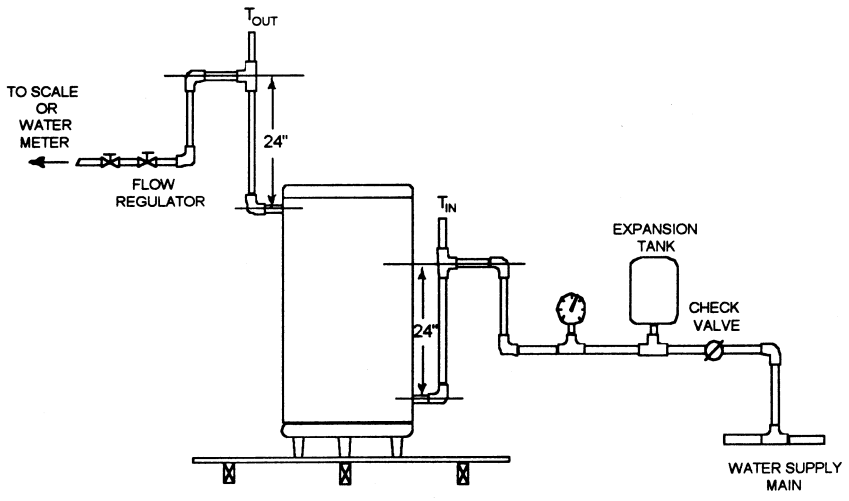

Figure 2.

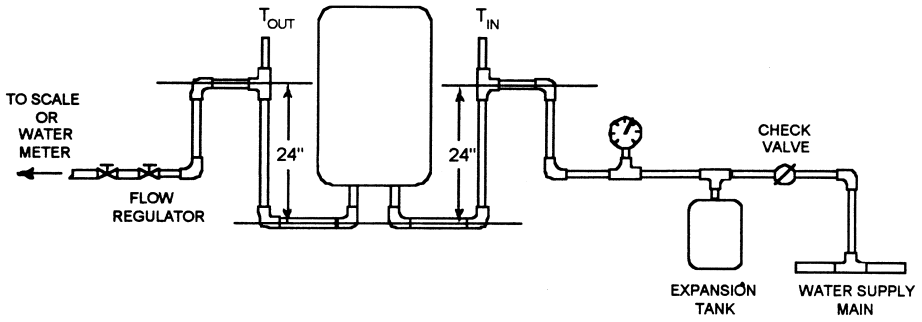

Figure 3.

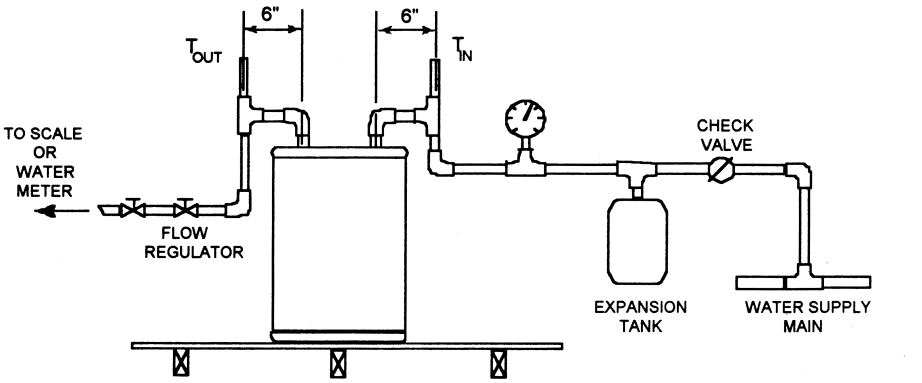

Figure 4.

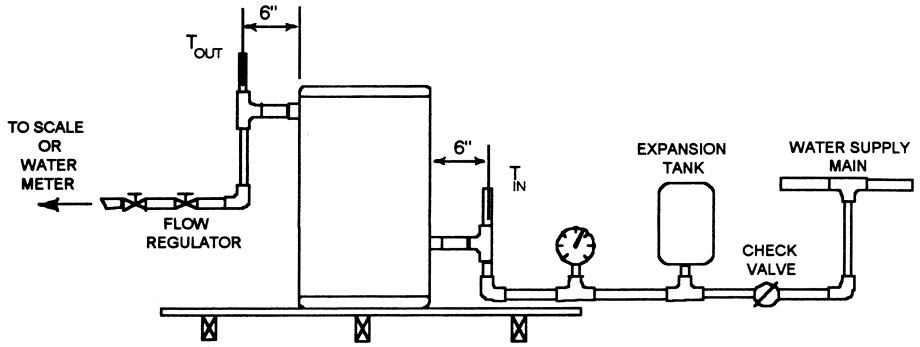

Figure 5.

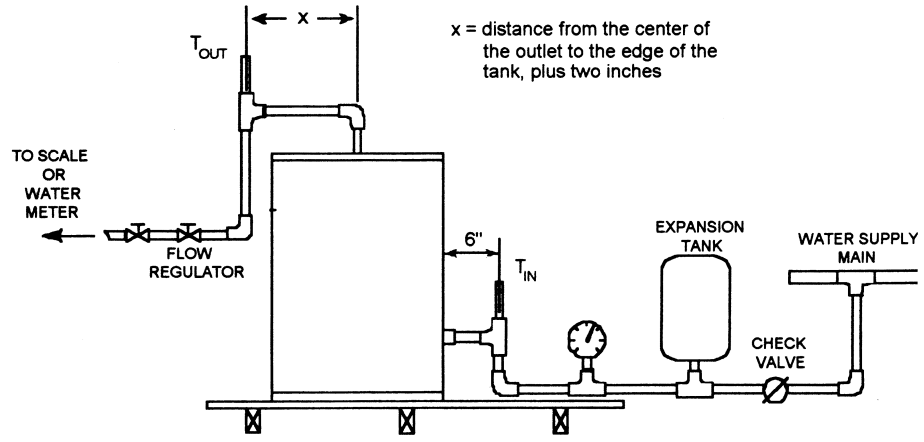

Figure 6.

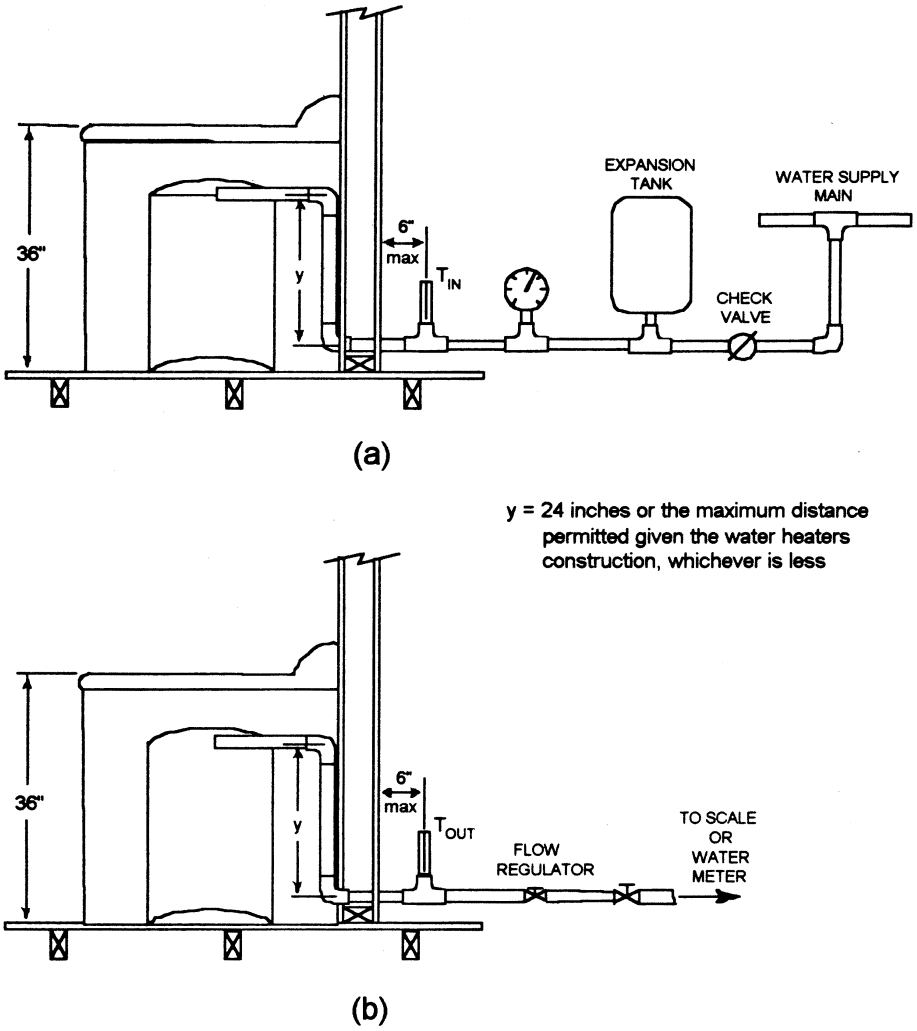

Figure 7.

4.4 *Fuel and/or Electrical Power and Energy Consumption.* Install one or more instruments which measure, as appropriate, the quantity and rate of electrical energy and/or fossil fuel consumption in accordance with Section 3. For heat pump water heaters that use supplemental resistive heating, the electrical energy supplied to the resistive element(s) shall be metered separately from the electrical energy supplied to the entire appliance or to the remaining components (e.g., compressor, fans, pumps, controls).

4.5 *Internal Storage Tank Temperature Measurements.* Install six temperature measurement sensors inside the water heater tank with a vertical distance of at least 4 inches (100 mm) between successive sensors. A temperature sensor shall be positioned at the vertical midpoint of each of the six equal

volume nodes within the tank. Nodes designate the equal volumes used to evenly partition the total volume of the tank. As much as is possible, the temperature sensor should be positioned away from any heating elements, anodic protective devices, tank walls, and flue pipe walls. If the tank cannot accommodate six temperature sensors and meet the installation requirements specified above, install the maximum number of sensors which comply with the installation requirements. The temperature sensors shall be installed either through (1) the anodic device opening; (2) the relief valve opening; or (3) the hot water outlet. If installed through the relief valve opening or the hot water outlet, a tee fitting or outlet piping, as applicable, shall be installed as close as possible to its original location. If the relief valve temperature sensor is relocated, and it no longer extends into the top of the tank, a substitute relief valve that has a sensing element that can reach into the tank shall be installed. If the hot water outlet includes a heat trap, the heat trap shall be installed on top of the tee fitting. Added fittings shall be covered with thermal insulation having an R value between 4 and 8 h/ft^{2+} °F/Btu (0.7 and 1.4 m^{2+} °C/W).

4.6 *Ambient Air Temperature Measurement.* Install an ambient air temperature sensor at the vertical mid-point of the water heater and approximately 2 feet (610 mm) from the surface of the water heater. The sensor shall be shielded against radiation.

4.7 *Inlet and Outlet Water Temperature Measurements.* Install temperature sensors in the cold-water inlet pipe and hot-water outlet pipe as shown in Figures 1, 2, 3, 4, 5, 6, 7a and 7b, as applicable.

4.8 *Flow Control.* A valve shall be installed to provide flow as specified in sections 5.1.4.1 for storage tank water heaters and 5.2.1 for instantaneous water heaters.

4.9 *Flue Requirements.*

4.9.1 *Gas-Fired Water Heaters.* Establish a natural draft in the following manner. For gas-fired water heaters with a vertically discharging draft hood outlet, a 5-foot (1.5-meter) vertical vent pipe extension with a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. For gas-fired water heaters with a horizontally discharging draft hood outlet, a 90-degree elbow with a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. A 5-foot (1.5-meter) length of vent pipe shall be connected to the elbow and oriented to discharge vertically upward. Direct vent gas-fired water heaters shall be installed with venting equipment specified in the manufacturer's instructions using the minimum vertical and horizontal lengths of vent pipe recommended by the manufacturer.

4.9.2 *Oil-Fired Water Heaters.* Establish a draft at the flue collar at the value specified in the manufacturer's instructions. Establish the draft by using a sufficient length of vent pipe connected to the water heater flue outlet, and directed vertically upward. For an oil-fired water heater with a horizontally discharging draft hood outlet, a 90-degree elbow with a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. A length of vent pipe sufficient to establish the draft shall be connected to the elbow fitting and oriented to discharge vertically upward. Direct-vent oil-fired water heaters should be installed with venting equipment as specified in the manufacturer's instructions, using the minimum vertical and horizontal lengths of vent pipe recommended by the manufacturer.

4.10 *Heat Pump Water Heater Storage Tank.* The tank to be used for testing a heat pump water heater without a tank supplied by the manufacturer (see Section 1.12.3b) shall be an electric storage-type water heater having a measured volume of 47.0 gallons ±1.0 gallon (178 liters ±3.8 liters); two 4.5 kW heating elements controlled in such a manner as to prevent both elements from operating simultaneously; and an energy factor greater than or equal to the minimum energy conservation standard (as determined in accordance with Section 6.1.7) and less than or equal to the sum of the minimum energy conservation standard and 0.02.

5. Test Procedures

5.1 *Storage-type Water Heaters, Including Heat Pump Water Heaters.*

5.1.1 *Determination of Storage Tank Volume.* Determine the storage capacity, V_{st}, of the water heater under test, in gallons (liters), by subtracting the tare weight—measured while the tank is empty—from the gross weight of the storage tank when completely filled with water (with all air eliminated and line pressure applied as described in section 2.5) and dividing the resulting net weight by the density of water at the measured temperature.

5.1.2 *Setting the Thermostat.*

5.1.2.1 *Single Thermostat Tanks.* Starting with a tank at the supply water temperature, initiate normal operation of the water heater. After cut-out, determine the mean tank temperature every minute until the maximum value is observed. Determine whether this maximum value for the mean tank temperature is within the range of 135 °F±5 °F (57.2 °C±2.8 °C). If not, turn off the water heater, adjust the thermostat, drain and refill the tank with supply water. Then, once again, initiate normal operation of the water heater, and determine the maximum mean tank temperature after cut-out. Repeat this sequence until the maximum mean

tank temperature after cut-out is 135 °F±5 °F (57.2 °C±2.8 °C).

5.1.2.2 *Tanks with Two or More Thermostats.* Follow the same sequence as for a single thermostat tank, i.e. start at the supply water temperature, operate normally until cutout. Determine if the thermostat that controls the uppermost heating element yields a maximum water temperature of 135 °F±5 °F (57.2 °C±2.8 °C), as measured by the in-tank sensors that are positioned above the uppermost heating element. If the tank temperature at the thermostat is not within 135 °F±5 °F (57.2 °C±2.8 °C), turn off the water heater, adjust the thermostat, drain and refill the tank with supply water. The thermostat that controls the heating element positioned next highest in the tank shall then be set to yield a maximum water temperature of 135 °F±5 °F (57.2 °C±2.8 °C). This process shall be repeated until the thermostat controlling the lowest element is correctly adjusted. When adjusting the thermostat that controls the lowest element, the maximum mean tank temperature after cut-out, as determined using all the in-tank sensors, shall be 135 °F±5 °F (57.2 °C±2.8 °C). When adjusting all other thermostats, use only the in-tank temperature sensors positioned above the heating element in question to evaluate the maximum water temperature after cut-out.

For heat pump water heaters that control an auxiliary resistive element, the thermostat shall be set in accordance with the manufacturer's installation instructions.

5.1.3 *Power Input Determination.* For all water heaters except electric types having immersed heating elements, initiate normal operation and determine the power input, P, to the main burners (including pilot light power, if any) after 15 minutes of operation. If the water heater is equipped with a gas appliance pressure regulator, the regulator outlet pressure shall be set within ±10% of that recommended by the manufacturer. For oil-fired water heaters the fuel pump pressure shall be within ±10% of the manufacturer's specified pump pressure. All burners shall be adjusted to achieve an hourly Btu (kJ) rating that is within ±2% of the value specified by the manufacturer. For an oil-fired water heater, adjust the burner to give a CO_2 reading recommended by the manufacturer and an hourly Btu (kJ) rating that is within ±2% of that specified by the manufacturer. Smoke in the flue may not exceed No. 1 smoke as measured by the procedure in ASTM–D–2156–80.

5.1.4 *First-Hour Rating Test.*

5.1.4.1 *General.* During hot water draws, remove water at a rate of 3.0±0.25 gallons per minute (11.4±0.95 liters per minute). Collect the water in a container that is large enough to hold the volume removed during an individual draw and suitable for weighing at the termination of each draw. Alternatively, a water meter may be used to directly measure the water volume(s) withdrawn.

5.1.4.2 *Draw Initiation Criteria.* Begin the first-hour rating test by imposing a draw on the storage-type water heater. After completion of this first draw, initiate successive draws based on the following criteria. For gas-and oil-fired water heaters, initiate successive draws when the thermostat acts to reduce the supply of fuel to the main burner. For electric water heaters having a single element or multiple elements that all operate simultaneously, initiate successive draws when the thermostat acts to reduce the electrical input supplied to the element(s). For electric water heaters having two or more elements that do not operate simultaneously, initiate successive draws when the applicable thermostat acts to reduce the electrical input to the element located vertically highest in the storage tank. For heat pump waters heaters that do not use supplemental resistive heating, initiate successive draws immediately after the electrical input to the compressor is reduced by the action of the water heater's thermostat. For heat pump waters heaters that use supplemental resistive heating, initiate successive draws immediately after the electrical input to the compressor or the uppermost resistive element is reduced by the action of the applicable water heater thermostat. This draw initiation criterion for heat pump water heaters that use supplemental resistive heating, however, shall only apply when the water located above the thermostat at cut-out is heated to 135 °F±5 °F (57.2 °C±2.8 °C).

5.1.4.3 *Test Sequence.* Establish normal water heater operation. If the water heater is not presently operating, initiate a draw. The draw may be terminated anytime after cut-in occurs. After cut-out occurs (i.e., all thermostats are satisfied), monitor the internal storage tank temperature sensors described in section 4.5 every minute.

Initiate a draw after a maximum mean tank temperature has been observed following cut-out. Record the time when the draw is initiated and designate it as an elapsed time of zero ($\tau^* = 0$). (The superscript * is used to denote variables pertaining to the first-hour rating test.) Record the outlet water temperature beginning 15 seconds after the draw is initiated and at 5-second intervals thereafter until the draw is terminated. Determine the maximum outlet temperature that occurs during this first draw and record it as $T^*_{max,\ 1}$. For the duration of this first draw and all successive draws, in addition, monitor the inlet temperature to the water heater to ensure that the required 58 °F±2 °F (14.4 °C±1.1 °C) test condition is met. Terminate the hot water draw when the outlet temperature decreases to $T^*_{max,1} - 25$ °F ($T^*_{max,1} - 13.9$ °C). Record this temperature as

$T^*_{min,1}$. Following draw termination, determine the average outlet water temperature and the mass or volume removed during this first draw and record them as $\bar{T}^*_{del,1}$ and M^*_1 or V^*_1, respectively.

Initiate a second and, if applicable, successive draw each time the applicable draw initiation criteria described in section 5.1.4.2 are satisfied. As required for the first draw, record the outlet water temperature 15 seconds after initiating each draw and at 5-second intervals thereafter until the draw is terminated. Determine the maximum outlet temperature that occurs during each draw and record it as $T^*_{max,\ i}$, where the subscript i refers to the draw number. Terminate each hot water draw when the outlet temperature decreases to $T^*_{max,\ i} - 25$ °F ($T^*_{max,\ i} - 13.9$ °C). Record this temperature as $T^*_{min,\ i}$. Calculate and record the average outlet temperature and the mass or volume removed during each draw ($\bar{T}^*_{del,\ i}$ and M^*_i or V^*_i, respectively). Continue this sequence of draw and recovery until one hour has elapsed, then shut off the electrical power and/or fuel supplied to the water heater.

If a draw is occurring at an elapsed time of one hour, continue this draw until the outlet temperature decreases to $T^*_{max,\ n} - 25$ °F ($T^*_{max,\ n} - 13.9$ °C), at which time the draw shall be immediately terminated. (The subscript n shall be used to denote quantities associated with the final draw.) If a draw is not occurring at an elapsed time of one hour, a final draw shall be imposed at one hour. This draw shall be immediately terminated when the outlet temperature first indicates a value less than or equal to the cut-off temperature used for the previous draw ($T^*_{min,\ n} - 1$). For cases where the outlet temperature is close to $T^*_{min,\ n} - 1$, the final draw shall proceed for a minimum of 30 seconds. If an outlet temperature greater than $T^*_{min,\ n} - 1$ is not measured within 30 seconds, the draw shall be immediately terminated and zero additional credit shall be given towards first-hour rating (i.e., $M^*_n = 0$ or $V^*_n = 0$). After the final draw is terminated, calculate and record the average outlet temperature and the mass or volume removed during the draw ($\bar{T}^*_{del,\ n}$ and M^*_n or V^*_n, respectively).

5.1.5 *24-Hour Simulated Use Test.* During the simulated use test, a total of 64.±3 1.0 gallons (243±3.8 liters) shall be removed. This value is referred to as the daily hot water usage in the following text.

With the water heater turned off, fill the water heater with supply water and apply pressure as described in section 2.5. Turn on the water heater and associated heat pump unit, if present. After the cut-out occurs, the water heater may be operated for up to three cycles of drawing until cut-in, and then operating until cut-out, prior to the start of the test.

At this time, record the mean tank temperature ($\bar{T}_o$), and the electrical and/or fuel measurement readings, as appropriate. Begin the 24-hour simulated use test by withdrawing a volume from the water heater that equals one-sixth of the daily hot water usage. Record the time when this first draw is initiated and assign it as the test elapsed time (τ) of zero (0). Record the average storage tank and ambient temperature every 15 minutes throughout the 24-hour simulated use test unless a recovery or a draw is occurring. At elapsed time intervals of one, two, three, four, and five hours from $\tau = 0$, initiate additional draws, removing an amount of water equivalent to one-sixth of the daily hot water usage with the maximum allowable deviation for any single draw being ±0.5 gallons (1.9 liters). The quantity of water withdrawn during the sixth draw shall be increased or decreased as necessary such that the total volume of water withdrawn equals 64.3 gallons ±1.0 gallon (243.4 liters ±3.8 liters).

All draws during the simulated use test shall be made at flow rates of 3.0 gallons ±0.25 gallons per minute (11.4 liters ±0.95 liters per minute). Measurements of the inlet and outlet temperatures shall be made 15 seconds after the draw is initiated and at every subsequent 5-second interval throughout the duration of each draw. The arithmetic mean of the hot water discharge temperature and the cold water inlet temperature shall be determined for each draw ($\bar{T}_{del,\ i}$ and $\bar{T}_{in,\ i}$). Determine and record the net mass or volume removed (M_i or V_i), as appropriate, after each draw.

At the end of the recovery period following the first draw, record the maximum mean tank temperature observed after cut-out, $\bar{T}_{max,\ 1}$, and the energy consumed by an electric resistance, gas or oil-fired water heater, Q_r. For heat pump water heaters, the total electrical energy consumed during the first recovery by the heat pump (including compressor, fan, controls, pump, etc.) and, if applicable, by the resistive element(s) shall be recorded as Q_r.

At the end of the recovery period that follows the sixth draw, determine and record the total electrical energy and/or fossil fuel consumed since the beginning of the test, Q_{su}. In preparation for determining the energy consumed during standby, record the reading given on the electrical energy (watt-hour) meter, the gas meter, and/or the scale used to determine oil consumption, as appropriate. Record the maximum value of the mean tank temperature after cut-out as $\bar{T}_{su}$. Except as noted below, allow the water heater to remain in the standby mode until 24 hours have elapsed from the start of the test (i.e., since = 0). Prevent the water heater from beginning a recovery cycle during the last hour of the test by turning off the electric power to the electrical heating elements and heat pump, if present, or by turning down the fuel supply to the main burner at

an elapsed time of 23 hours. If a recovery is taking place at an elapsed time of 23 hours, wait until the recovery is complete before reducing the electrical and/or fuel supply to the water heater. At 24 hours, record the mean tank temperature, $\bar{T}_{24}$, and the electric and/or fuel instrument readings. Determine the total fossil fuel or electrical energy consumption, as appropriate, for the entire 24-hour simulated use test, Q. Record the time interval between the time at which the maximum mean tank temperature is observed after the sixth draw and the end of the 24-hour test as $_{stby,\ 1}$. Record the time during which water is not being withdrawn from the water heater during the entire 24-hour period as $_{stby,\ 2}$.

5.2 *Instantaneous Gas and Electric Water Heaters*

5.2.1 *Setting the Outlet Discharge Temperature.* Initiate normal operation of the water heater at the full input rating for electric instantaneous water heaters and at the maximum firing rate specified by the manufacturer for gas instantaneous water heaters. Monitor the discharge water temperature and set to a value of 135 °F ±5 °F (57.2 °C ±2.8 °C) in accordance with the manufacturer's instructions. If the water heater is not capable of providing this discharge temperature when the flow rate is 3.0 gallons ±0.25 gallons per minute (11.4 liters ±0.95 liters per minute), then adjust the flow rate as necessary to achieve the specified discharge water temperature. Record the corresponding flow rate as V_{max}.

5.2.2 *Additional Requirements for Variable Input Instantaneous Gas Water Heaters.* If the instantaneous water heater incorporates a controller that permits operation at a reduced input rate, adjust the flow rate as necessary to achieve a discharge water temperature of 135 °F ±5 °F (57.2 °C ±2.8 °C) while maintaining the minimum input rate. Record the corresponding flow rate as V_{min}. If an outlet temperature of 135 °F ±5 °F (57.2 °C ±2.8 °C) cannot be achieved at the minimum flow rate permitted by the instantaneous water heater, record the flow rate as V_{min} and the corresponding outlet temperature as T_{min}.

5.2.3 *Maximum GPM Rating Test for Instantaneous Water Heaters.* Establish normal water heater operation at the full input rate for electric instantaneous water heaters and at the maximum firing rate for gas instantaneous water heaters with the discharge water temperature set in accordance with Section 5.2.1. During the 10-minute test, either collect the withdrawn water for later measurement of the total mass removed, or alternatively, use a water meter to directly measure the water volume removed.

After recording the scale or water meter reading, initiate water flow throughout the water heater, record the inlet and outlet water temperatures beginning 15 seconds after the start of the test and at subsequent 5-second intervals throughout the duration of the test. At the end of 10 minutes, turn off the water. Determine the mass of water collected, M_{10m}, in pounds (kilograms), or the volume of water, V_{10m}, in gallons (liters).

5.2.4 *24-hour Simulated Use Test for Gas Instantaneous Water Heaters.*

5.2.4.1 *Fixed Input Instantaneous Water Heaters.* Establish normal operation with the discharge water temperature and flow rate set to values of 135 °F ±5 °F (57.2 °C ±2.8 °C) and V_{max} per Section 5.2.1, respectively. With no draw occurring, record the reading given by the gas meter and/or the electrical energy meter as appropriate. Begin the 24-hour simulated use test by drawing an amount of water out of the water heater equivalent to one-sixth of the daily hot water usage. Record the time when this first draw is initiated and designate it as an elapsed time, τ, of 0. At elapsed time intervals of one, two, three, four, and five hours from $\tau = 0$, initiate additional draws, removing an amount of water equivalent to one-sixth of the daily hot water usage, with the maximum allowable deviation for any single draw being ±0.5 gallons (1.9 liters). The quantity of water drawn during the sixth draw shall be increased or decreased as necessary such that the total volume of water withdrawn equals 64.3 gallons ±1.0 gallons (243.4 liters ±3.8 liters).

Measurements of the inlet and outlet water temperatures shall be made 15 seconds after the draw is initiated and at every 5-second interval thereafter throughout the duration of the draw. The arithmetic mean of the hot water discharge temperature and the cold water inlet temperature shall be determined for each draw. Record the scale used to measure the mass of the withdrawn water or the water meter reading, as appropriate, after each draw. At the end of the recovery period following the first draw, determine and record the fossil fuel or electrical energy consumed, Q_r. Following the sixth draw and subsequent recovery, allow the water heater to remain in the standby mode until exactly 24 hours have elapsed since the start of the test (i.e., since $\tau = 0$). At 24 hours, record the reading given by the gas meter and/or the electrical energy meter as appropriate. Determine the fossil fuel or electrical energy consumed during the entire 24-hour simulated use test and designate the quantity as Q.

5.2.4.2 *Variable Input Instantaneous Water Heaters.* If the instantaneous water heater incorporates a controller that permits continuous operation at a reduced input rate, the first three draws shall be conducted using the maximum flow rate, V_{max}, while removing an amount of water equivalent to one-sixth of the daily hot water usage, with the maximum allowable deviation for any one of the three draws being ±0.5 gallons (1.9 liters).

The second three draws shall be conducted at V_{min}. If an outlet temperature of 135 °F ±5 °F (57.2 °C ±2.8 °C) could not be achieved at the minimum flow rate permitted by the instantaneous water heater, the last three draws should be lengthened such that the volume removed is:

$$V_{4,5,6} = \frac{64.3\ \text{gal}}{6} \times \left[\frac{77°\text{F}}{(T_{min} - 58°\text{F})} \right]$$

or

$$V_{4,5,6} = \frac{243\ \text{L}}{6} \times \left[\frac{42.8°\text{C}}{(T_{min} - 14.4°\text{C})} \right]$$

where T_{min} is the outlet water temperature at the flow rate V_{min} as determined in Section 5.2.1, and where the maximum allowable variation for any one of the three draws is ±0.5 gallons (1.9 liters). The quantity of water withdrawn during the sixth draw shall be increased or decreased as necessary such that the total volume of water withdrawn equals (32.15 + 3÷$V_{4,5,6}$) ±1.0 gallons

((121.7 + 3 ÷ $V_{4,5,6}$) ±3.8 liters).

Measurements of the inlet and outlet water temperatures shall be made 5 seconds after a draw is initiated and at every 5-second interval thereafter throughout the duration of the draw. Determine the arithmetic mean of the hot water discharge temperature and the cold water inlet temperature for each draw. Record the scale used to measure the mass of the withdrawn water or the water meter reading, as appropriate, after each draw. At the end of the recovery period following the first draw, determine and record the fossil fuel or electrical energy consumed, $Q_{r,\ max}$. Likewise, record the reading of the meter used to measure fossil fuel or electrical energy consumption prior to the fourth draw and at the end of the recovery period following the fourth draw, and designate the difference as $Q_{r,min}$. Following the sixth draw and subsequent recovery, allow the water heater to remain in the standby mode until exactly 24 hours have elapsed since the start of the test (i.e., since τ=0). At 24 hours, record the reading given by the gas meter and/or the electrical energy meter, as appropriate. Determine the fossil fuel or electrical energy consumed during the entire 24-hour simulated use test and designate the quantity as Q.

6. Computations

6.1 *Storage Tank and Heat Pump Water Heaters.*

6.1.1 *Storage Tank Capacity.* The storage tank capacity is computed using the following:

$$V_{st} = \frac{(W_f - W_t)}{\rho}$$

Where:

V_{st} = the storage capacity of the water heater, gal (L).

W_f = the weight of the storage tank when completely filled with water, lb (kg).

W_t = the (tare) weight of the storage tank when completely empty, lb (kg).

ρ = the density of water used to fill the tank measured at the temperature of the water, lb/gal (kg/L).

6.1.2. *First-Hour Rating Computation.* For the case in which the final draw is initiated at or prior to an elapsed time of one hour, the first-hour rating shall be computed using,

$$F_{hr} = \sum_{i=1}^{n} V_i^*$$

Where:

n = the number of draws that are completed during the first-hour rating test.

V^*_i = the volume of water removed during the *ith* draw of the first-hour rating test, gal (L)

or, if the mass of water is being measured,

$$V_i^* = \frac{M_i^*}{\rho}$$

Where:

M^*_i = the mass of water removed during the ith draw of the first-hour rating test, lb (kg).

ρ = the water density corresponding to the average outlet temperature measured during the *ith* draw, ($\bar{T}^*_{del,\ i}$), lb/gal (kg/L).

For the case in which a draw is not in progress at the elapsed time of one hour and a final draw is imposed at the elapsed time of one hour, the first-hour rating shall be calculated using

$$F_{hr} = \sum_{i=1}^{n-1} V_i^* + V_n^* \left(\frac{\overline{T}^*_{del,\ n} - T^*_{min,\ n-1}}{\overline{T}^*_{del,\ n-1} - T^*_{min,\ n-1}} \right)$$

where *n* and V^*_i are the same quantities as defined above, and

V^*_n = the volume of water drawn during the nth (final) draw of the first-hour rating test, gal (L)

$\bar{T}^*_{del,n-1}$ = the average water outlet temperature measured during the $(n-1)$th draw of the first-hour rating test, °F (°C).

$\bar{T}^*_{del,n}$ = the average water outlet temperature measured during the *n*th (final) draw of the first-hour rating test, °F (°C).

$\bar{T}^*_{min,n-1}$ = the minimum water outlet temperature measured during the $(n-1)$th draw of the first-hour rating test, °F (°C).

6.1.3 *Recovery Efficiency*. The recovery efficiency for gas, oil, and heat pump storage-type water heaters is computed as:

$$\eta_r = \frac{M_1 C_{p1}\left(\overline{T}_{del,1} - \overline{T}_{in,1}\right)}{Q_r} + \frac{V_{st}\rho_2 C_{p2}\left(\overline{T}_{max,1} - \overline{T}_o\right)}{Q_r}$$

Where:

M_1 = total mass removed during the first draw of the 24-hour simulated use test, lb (kg), or, if the volume of water is being measured,

$M_1 = V_1 \rho_1$

Where:

V_1 = total volume removed during the first draw of the 24-hour simulated use test, gal (L).

ρ_1 = density of the water at the water temperature measured at the point where the flow volume is measured, lb/gal (kg/L).

C_{p1} = specific heat of the withdrawn water, $(\bar{T}_{del,1} + \bar{T}_{in,1})$ 2, Btu/lb °F (kJ/kg °C).

$\bar{T}_{del,1}$ = average water outlet temperature measured during the first draw of the 24-hour simulated use test, °F (°C).

$\bar{T}_{in,1}$ = average water inlet temperature measured during the first draw of the 24-hour simulated use test, °F (°C).

V_{st} = as defined in section 6.1.1.

ρ_2 = density of stored hot water, $(\bar{T}_{max,1} + \bar{T}_o)$/ 2, lb/gal (kg/L).

C_{p2} = specific heat of stored hot water evaluated at $(\bar{T}_{max,1} + \bar{T}_o)$ / 2, Btu/lb °F (kJ/kg$_2$ °C).

$\bar{T}_{max,1}$ = maximum mean tank temperature recorded after cut-out following the first draw of the 24-hour simulated use test, °F (°C).

$\bar{T}_o$ = maximum mean tank temperature recorded prior to the first draw of the 24-hour simulated use test, °F (°C).

Q_r = the total energy used by the water heater between cut-out prior to the first draw and cut-out following the first draw, including auxiliary energy such as pilot lights, pumps, fans, etc., Btu (kJ). (Electrical auxiliary energy shall be converted to thermal energy using the following conversion: 1 kWh = 3,412 Btu.)

The recovery efficiency for electric water heaters with immersed heating elements is assumed to be 98%.

6.1.4 *Hourly Standby Losses*. The hourly standby energy losses are computed as:

$$Q_{hr} = \frac{Q_{stby} - \dfrac{V_{st}\rho C_p\left(\overline{T}_{24} - \overline{T}_{su}\right)}{\eta_r}}{\tau_{stby,1}}$$

Where:

Q_{hr} = the hourly standby energy losses of the water heater, Btu/h (kJ/h).

Q_{stby} = the total energy consumed by the water heater between the time at which the maximum mean tank temperature is observed after the sixth draw and the end of the 24-hour test period, Btu (kJ).

V_{st} = as defined in section 6.1.1.

ρ = density of stored hot water, $(\bar{T}_{24} + \bar{T}_{su})$ / 2, lb/gal (kg/L).

C_p = specific heat of the stored water, $(\bar{T}_{24} + \bar{T}_{su})$ / 2, Btu/lb÷°F (kJ/kg÷°C).

$\bar{T}_{24}$ = the mean tank temperature at the end of the 24-hour simulated use test, °F (°C).

$\bar{T}_{su}$ = the maximum mean tank temperature observed after the sixth draw, °F (°C).

η_r = as defined in section 6.1.3.

$\tau_{stby,\ 1}$ = elapsed time between the time at which the maximum mean tank temperature is observed after the sixth draw and the end of the 24-hour simulated use test, h.

The standby heat loss coefficient for the tank is computed as:

$$UA = \frac{Q_{hr}}{\overline{T}_{t,\,stby,1} - \overline{T}_{a,\,stby,1}}$$

Where:

UA = standby heat loss coefficient of the storage tank, Btu/h÷°F (kJ/h÷°C).

Q_{hr} = as defined in this section.

$\bar{T}_{t,\ stby,1}$= overall average storage tank temperature between the time when the maximum mean tank temperature is observed after the sixth draw and the end of the 24-hour simulated use test, °F (°C).

$\bar{T}_{a,\ stby,1}$= overall average ambient temperature between the time when the maximum mean tank temperature is observed after the sixth draw and the end of the 24-hour simulated use test, °F (°C).

6.1.5 *Daily Water Heating Energy Consumption*. The daily water heating energy consumption, Q_d, is computed as:

$$Q_d = Q - \frac{V_{st}\rho C_p\left(\overline{T}_{24} - \overline{T}_o\right)}{\eta_r}$$

Where:

Q = total energy used by the water heater during the 24-hour simulated use test including auxiliary energy such as pilot lights, pumps, fans, etc., Btu (kJ). (Electrical auxiliary energy shall be converted to thermal energy using the following conversion: 1 kWh = 3,412 Btu.)

V_{st} = as defined in section 6.1.1.

ρ= density of the stored hot water, $(\bar{T}_{24} + \bar{T}_o) / 2$, lb/gal (kg/L).

C_p = specific heat of the stored water, $(\bar{T}_{24} + \bar{T}_o) / 2$, Btu/lb÷°F (kJ/kg÷°C).

$\bar{T}_{24}$ = mean tank temperature at the end of the 24-hour simulated use test, °F (°C).

$\bar{T}_o$ = mean tank temperature at the beginning of the 24-hour simulated use test, recorded one minute before the first draw is initiated, °F (°C).

η_r = as defined in section 6.1.3.

6.1.6 *Adjusted Daily Water Heating Energy Consumption*. The adjusted daily water heating energy consumption, Q_{da}, takes into account that the temperature difference between the storage tank and surrounding ambient air may not be the nominal value of 67.5 °F (135 °F–67.5 °F) or 37.5 °C (57.2 °C–19.7 °C) due to the 10 °F (5.6 °C) allowable variation in storage tank temperature, 135 °F ±5 °F (57.2 °C ±2.8 °C), and the 5 °F (2.8 °C) allowable variation in surrounding ambient temperature 65 °F (18.3 °C) to 70 °F (21.1 °C). The adjusted daily water heating energy consumption is computed as:

$Q_{da} = Q_D - [(\bar{T}_{stby,\ 2} - \bar{T}_{a,\ stby,2}) - (135\ °F - 67.5\ °F)]\ UA\tau_{stby,\ 2}$

or $Q_{da} = Q_D - [(\bar{T}_{stby,\ 2} - \bar{T}_{a,\ stby,\ 2}) - (57.2\ °C - 19.7\ °C)]\ UA\tau_{stby,\ 2}$

Where:

Q_{da} = the adjusted daily water heating energy consumption, Btu (kJ).

Q_d = as defined in section 6.1.5.

$\bar{T}_{stby,\ 2}$ = the mean tank temperature during the total standby portion, $\tau_{stby,\ 2}$, of the 24-hour test, °F (°C).

$\bar{T}_{a,\ stby,\ 2}$ = the average ambient temperature during the total standby portion, $\tau_{stby,\ 2}$, of the 24-hour test, °F (°C).

UA = as defined in section 6.1.4.

$\tau_{stby,\ 2}$ = the number of hours during the 24-hour simulated test when water is not being withdrawn from the water heater.

A modification is also needed to take into account that the temperature difference between the outlet water temperature and supply water temperature may not be equivalent to the nominal value of 77 °F (135 °F–58 °F) or 42.8 °C (57.2 °C–14.4 °C). The following equations adjust the experimental data to a nominal 77 °F (42.8 °C) temperature rise.

The energy used to heat water, Btu/day (kJ/day), may be computed as:

$$Q_{HW} = \sum_{i=1}^{6} \frac{M_i C_{pi}\left(\overline{T}_{del,\,i} - \overline{T}_{in,\,i}\right)}{\eta_r}$$

Where:

M_i = the mass withdrawn for the *i*th draw (i = 1 to 6), lb (kg).

C_{pi} = the specific heat of the water of the *i*th draw, Btu/lb÷ °F (kJ/kg÷ °C).

$\bar{T}_{del,\ i}$ = the average water outlet temperature measured during the *i*th draw (i=1 to 6), °F (°C).

$\bar{T}_{in,\ i}$ = the average water inlet temperature measured during the *i*th draw (i=1 to 6), °F (°C).

η_r = as defined in section 6.1.3.

The energy required to heat the same quantity of water over a 77 °F (42.8 °C) temperature rise, Btu/day (kJ/day), is:

$$Q_{HW,\,77°F} = \sum_{i=1}^{6} \frac{M_i C_{pi}(135°F - 58°F)}{\eta_r}$$

$$\text{or } Q_{HW,\,42.8°C} = \sum_{i=1}^{6} \frac{M_i C_{pi}(57.2°C - 14.4°C)}{\eta_r}$$

The difference between these two values is:

$Q_{HWD} = Q_{HW,\ 77° - F} - Q_{HW}$

or $Q_{HWD} = Q_{HW,42.8° - F} - Q_{HW}$

which must be added to the adjusted daily water heating energy consumption value. Thus, the daily energy consumption value which takes into account that the temperature difference between the storage tank and ambient temperature may not be 67.5 °F (37.5 °C) and that the temperature rise across the storage tank may not be 77 °F (42.8 °C) is:

$Q_{dm} = Q_{da} + Q_{HWD}$

6.1.7 Energy Factor. The energy factor, Ef, is computed as:

$$E_f = \sum_{i=1}^{6} \frac{M_i C_{pi}(135° F - 58° F)}{Q_{dm}}$$

or

$$E_f = \sum_{i=1}^{6} \frac{M_i C_{pi}(57.2° C - 14.4° C)}{Q_{dm}}$$

Where:

Q_{dm} = the modified daily water heating energy consumption as computed in accordance with section 6.1.6, Btu (kJ).

M_i = the mass withdrawn for the ith draw (i = 1 to 6), lb (kg).

C_{pi} = the specific heat of the water of the ith draw, Btu/lb °F (kJ/kg °C).

6.1.8 *Annual Energy Consumption*. The annual energy consumption for storage-type and heat pump water heaters is computed as:

$E_{annual} = 365 \times Q_{dm}$

Where:

Q_{dm} = the modified daily water heating energy consumption as computed in accordance with section 6.1.6, Btu (kJ).

365 = the number of days in a year.

6.2 *Instantaneous Water Heaters.*

6.2.1 *Maximum GPM (L/min) Rating Computation.* Compute the maximum gpm (L/min) rating as:

$$F_{max} = \frac{M_{10m}\left(\overline{T}_{del} - \overline{T}_{in}\right)}{10(\rho)(135°F - 58°F)}$$

$$\text{or } F_{max} = \frac{M_{10m}\left(\overline{T}_{del} - \overline{T}_{in}\right)}{10(\rho)(57.2°C - 14.4°C)}$$

which may be expressed as:

$$F_{max} = \frac{M_{10m}\left(\overline{T}_{del} - \overline{T}_{in}\right)}{10(\rho)(77°F)}$$

$$\text{or } F_{max} = \frac{M_{10m}\left(\overline{T}_{del} - \overline{T}_{in}\right)}{10(\rho)(42.8°C)}$$

Where:

M_{10m} = the mass of water collected during the 10-minute test, lb (kg).

$\bar{T}_{del}$ = the average delivery temperature, °F (°C).

$\bar{T}_{in}$ = the average inlet temperature, °F (°C).

ρ = the density of water at the average delivery temperature, lb/gal (kg/L).

If a water meter is used the maximum gpm (L/min) rating is computed as:

$$F_{max} = \frac{V_{10m}\left(\overline{T}_{del} - \overline{T}_{in}\right)}{10(77°F)}$$

$$\text{or } F_{max} = \frac{V_{10m}\left(\overline{T}_{del} - \overline{T}_{in}\right)}{10(42.8°C)}$$

Where:

V_{10m} = the volume of water measured during the 10-minute test, gal (L).

$\bar{T}_{del}$ = as defined in this section.

$\bar{T}_{in}$ = as defined in this section.

6.2.2 *Recovery Efficiency*

6.2.2.1 *Fixed Input Instantaneous Water Heaters.* The recovery efficiency is computed as:

$$\eta_r = \frac{M_1 C_{p1}\left(\overline{T}_{del,1} - \overline{T}_{in,1}\right)}{Q_r}$$

Where:

M_1 = total mass removed during the first draw of the 24-hour simulated use test, lb (kg), or, if the volume of water is being measured,

$M_1 = V_1 \cdot \rho$

Where:

V_1 = total volume removed during the first draw of the 24-hour simulated use test, gal (L).

ρ= density of the water at the water temperature measured at the point where the flow volume is measured, lb/gal (kg/L).

C_{p1} = specific heat of the withdrawn water, $(\bar{T}_{del,1} + T_{in,1}) / 2$, Btu/lb °F (kJ/kg °C).

$\bar{T}_{del,\ 1}$ = average water outlet temperature measured during the first draw of the 24-hour simulated use test, °F (°C).

$\bar{T}_{in,\ 1}$ = average water inlet temperature measured during the first draw of the 24-hour simulated use test, °F (°C).

Q_r = the total energy used by the water heater between cut-out prior to the first draw and cut-out following the first draw, including auxiliary energy such as pilot lights, pumps, fans, etc., Btu (kJ). (Electrical auxiliary energy shall be converted to thermal energy using the following conversion: 1 kWh = 3,412 Btu.)

6.2.2.2 *Variable Input Instantaneous Water Heaters.* For instantaneous water heaters that have a variable firing rate, two recovery efficiency values are computed, one at the maximum input rate and one at the minimum input rate. The recovery efficiency used in subsequent computations is taken as the average of these two values. The maximum recovery efficiency is computed as:

$$\eta_{r,\,max} = \frac{M_1 C_{p1}\left(\overline{T}_{del,1} - \overline{T}_{in,1}\right)}{Q_{r,\,max}}$$

Where:

M_1 = as defined in section 6.2.2.1.

C_{p1} = as defined in section 6.2.2.1.

$\bar{T}_{del,\ 1}$ = as defined in section 6.2.2.1.

$\bar{T}_{in,\ 1}$ = as defined in section 6.2.2.1.

$Q_{r,\ max}$ = the total energy used by the water heater between burner cut-out prior to the first draw and burner cut-out following the first draw, including auxiliary energy such as pilot lights, Btu (kJ).

The minimum recovery efficiency is computed as:

$$\eta_{r,\,min} = \frac{M_4 C_{p4}\left(\overline{T}_{del,4} - \overline{T}_{in,4}\right)}{Q_{r,\,min}}$$

Where:

M_4 = the mass withdrawn during the fourth draw, lb (kg), or, if the volume of water is being measured,

$M_4 = V_4\ \rho$

Where:

V_4 = total volume removed during the first draw of the 24-hour simulated use test, gal (L).

ρ = as defined in 6.2.2.1

C_{p4} = the specific heat of water, Btu/lb °F (kJ/kg °C).

$\bar{T}_{del,\ 4}$ = the average delivery temperature for the fourth draw, °F (°C).

$\bar{T}_{in,\ 4}$ = the average inlet temperature for the fourth draw, °F (°C).

$Q_{r,\ min}$ = the total energy consumed between the beginning of the fourth draw and burner cut-out following the fourth draw, including auxiliary energy such as pilot lights, Btu (kJ).

The recovery efficiency is computed as:

$$\eta_r = \frac{\eta_{r,\max} + \eta_{r,\min}}{2}$$

Where:

$\eta_{r,max}$ = as calculated above.

$\eta_{r,min}$ = as calculated above.

6.2.3 *Daily Water Heating Energy Consumption*. The daily water heating energy consumption, Q_d, is computed as:

$Q_d = Q$

Where:

Q = the energy used by the instantaneous water heater during the 24-hr simulated use test.

A modification is needed to take into account that the temperature difference between the outlet water temperature and supply water temperature may not be equivalent to the nominal value of 77 °F (135 °F − 58 °F) or 42.8 °C (57.2 °C − 14.4 °C). The following equations adjust the experimental data to a nominal 77 °F (42.8 °C) temperature rise.

The energy used to heat water may be computed as:

$$Q_{HW} = \sum_{i=1}^{6} \frac{M_i C_{pi}\left(\overline{T}_{del,i} - \overline{T}_{in,i}\right)}{\eta_r}$$

Where:

M_i = the mass withdrawn during the ith draw, lb (kg).

C_{pi} = the specific heat of water of the ith draw, Btu/lb °F (kJ/kg (°C).

$\bar{T}_{del,i}$ = the average delivery temperature of the ith draw, °F (°C).

$\bar{T}_{in,i}$ = the average inlet temperature of the ith draw, °F (°C).

η_r = as calculated in section 6.2.2.2.

The energy required to heat the same quantity of water over a 77 °F (42.8 °C) temperature rise is:

$$Q_{HW,\ 77°F} = \sum_{i=1}^{6} \frac{M_i C_{pi}(135°F - 58°F)}{\eta_r}$$

$$\text{or } Q_{HW,\ 42.8°C} = \sum_{i=1}^{6} \frac{M_i C_{pi}(57.2°C - 14.4°C)}{\eta_r}$$

Where:

M_i = the mass withdrawn during the *i*th draw, lb (kg).

C_{pi} = the specific heat of water of the ith draw, Btu/lb °F (kJ/kg (°C).

η_r = as calculated above.

The difference between these two values is:

$Q_{HWD} = Q_{HW,\ 77\ °F} - Q_{HW}$
or $Q_{HWD} = Q_{HW,\ 42.8\ °C} - Q_{HW}$

which much be added to the daily water heating energy consumption value. Thus, the daily energy consumption value which takes into account that the temperature rise across the storage tank may not be 77 °F (42.8 °C) is:

$Q_{dm} = Q_d + Q_{HWD}$

6.2.4 *Energy Factor*. The energy factor, E_f, is computed as:

$$E_f = \sum_{i=1}^{6} \frac{M_i C_{pi}(135°F - 58°F)}{Q_{dm}}$$

$$\text{or } E_f = \sum_{i=1}^{6} \frac{M_i C_{pi}(57.2°C - 14.4°C)}{Q_{dm}}$$

Where:

Q_{dm} = the daily water heating energy consumption as computed in accordance with section 6.2.3, Btu (kJ).

M_i = the mass associated with the *i*th draw, lb (kg).

C_{pi} = the specific heat of water computed at a temperature of (58 °F + 135 °F) / 2, Btu/lb °F [(14.4 °C + 57.2 °C) / 2, kJ/kg °C].

6.2.5 *Annual Energy Consumption*. The annual energy consumption for instantaneous type water heaters is computed as:

$E_{annual} = 365 \times Q_{dm}$

Where:

Q_{dm} = the modified daily energy consumption, Btu/day (kJ/day).

365 = the number of days in a year.

7. Ratings for Untested Models

In order to relieve the test burden on manufacturers who offer water heaters which differ only in fuel type or power input, ratings for untested models may be established in accordance with the following procedures. In lieu of the following procedures a manufacturer may elect to test the unit for which a rating is sought.

7.1 *Gas Water Heaters.* Ratings obtained for gas water heaters using natural gas can be used for an identical water heater which utilizes propane gas if the input ratings are within ±10%.

7.2 *Electric Water Heaters*

7.2.1 *First-Hour Rating.* If an electric storage-type water heater is available with more than one input rating, the manufacturer shall designate the standard input rating, and the water heater need only be tested with heating elements at the designated standard input ratings. The first-hour ratings for units having power input rating less than the designated standard input rating shall be assigned a first-hour rating equivalent to the first draw of the first-hour rating for the electric water heater with the standard input rating. For units having power inputs greater than the designated standard input rating, the first-hour rating shall be equivalent to that measured for the water heater with the standard input rating.

7.2.2 *Energy Factor.* The energy factor for identical electric storage-type water heaters, with the exception of heating element wattage, may use the energy factor obtained during testing of the water heater with the designated standard input rating.

[63 FR 26008, May 11, 1998; 63 FR 38738, July 20, 1998, as amended at 66 FR 4497, Jan. 17, 2001]

APPENDIX F TO SUBPART B OF PART 430—UNIFORM TEST METHOD FOR MEASURING THE ENERGY CONSUMPTION OF ROOM AIR CONDITIONERS

NOTE: Manufacturers are not required to use the test procedures and calculations that refer to standby mode and off mode energy consumption, (specifically, sections 2.2, 3.2, 4.2, and 5.3 of this appendix F) until the compliance date of any amended energy conservation standards for room air conditioners at 10 CFR 430.32(b).

1. *Definitions.*

1.1 ''Active mode'' means a mode in which the room air conditioner is connected to a mains power source, has been activated and is performing the main function of cooling or heating the conditioned space, or circulating air through activation of its fan or blower, with or without energizing active air-cleaning components or devices such as ultraviolet (UV) radiation, electrostatic filters, ozone generators, or other air-cleaning devices.

1.2 ''ANSI/AHAM RAC–1'' means the test standard published jointly by the American National Standards Institute and the Association of Home Appliance Manufacturers, titled ''Room Air Conditioners,'' Standard RAC–1–2008 (incorporated by reference; see §430.3).

1.3 ''ANSI/ASHRAE 16'' means the test standard published jointly by the American National Standards Institute and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers titled ''Method of Testing for Rating Room Air Conditioners and Packaged Terminal Air Conditioners,'' Standard 16–1983 (RA 2009) (incorporated by reference; see §430.3).

1.4 ''IEC 62301'' means the test standard published by the International Electrotechnical Commission, (''IEC''), titled ''Household electrical appliances—Measurement of standby power,'' Publication 62301 (first edition June 2005), (incorporated by reference; see §430.3).

1.5 ''Inactive mode'' means a standby mode that facilitates the activation of active mode by remote switch (including remote control) or internal sensor or which provides continuous status display.

1.6 ''Off mode'' means a mode in which a room air conditioner is connected to a mains power source and is not providing any active or standby mode function and where the mode may persist for an indefinite time. An indicator that only shows the user that the product is in the off position is included within the clasification of an off mode.

1.7 ''Standby mode'' means any product modes where the where the energy using product is connected to a mains power source and offers one or more of the following user oriented or protective functions which may persist for an indefinite time:

(a) To facilitate the activation of other modes (including activation or deactivation of active mode) by remote switch (including remote control), internal sensor, or timer.

(b) Continuous functions, including information or status displays (including clocks) or sensor-based functions. A timer is a continuous clock function (which may or may not be associated with a display) that provides regular scheduled tasks (*e.g.*, switching) and that operates on a continuous basis.

2. *Test methods.*

2.1 *Cooling.* The test method for testing room air conditioners in cooling mode shall consist of application of the methods and conditions in ANSI/AHAM RAC–1 sections 4, 5, 6.1, and 6.5 (incorporated by reference; see §430.3), and in ANSI/ASHRAE 16 (incorporated by reference; see §430.3).

2.2 *Standby and off modes.* The method for testing room air conditioners in standby and off modes shall consist of application of the methods and conditions in IEC 62301 (incorporated by reference; see §430.3), as modified by the requirements of this standard. The testing may be conducted in test facilities used for testing cooling performance. If testing is not conducted in such a facility, the test facility shall comply with IEC 62301 section 4.2.

3. *Test conditions.*